SL 302

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IFAS Extension

Environmental Consequences of Water Withdrawals and Drainage of Wetlands[1]

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Introduction

Riparian and floodplain wetlands are ecologically important parts of the Florida landscape. By virtue of their low-lying position in the landscape, they receive hydrologic and nutrient inputs from adjacent upland areas. As such, wetlands serve as buffers to rivers and lakes and absorb contaminants and nutrients before they reach aquatic systems. The retention of floodwater during wet seasons results in accumulation of organic matter and accretion of nutrients and low rates of decomposition, which build up deep layers of soil. Because of their high primary production and low decomposition rate, wetland soils serve to sequester carbon and nutrients. However, these benefits are negated whenever changes in hydrologic conditions, such as water withdrawals or drought, occur.

The objective of this document is to educate the general public about how hydrologic conditions, such as drought and water withdrawal, influence the functioning and benefits of wetland ecosystems.

Wetland Soils

Accumulation of the organic soils characteristically associated with wetlands can take hundreds or even thousands of years. The stability of these soils is highly dependent on hydrology as their formation is due to the historically extended hydroperiod. In some regions, wetland hydrology has been dramatically altered, resulting in substantial loss of organic soils (histosols). Histosols are naturally productive and contain large amounts of organic carbon, nitrogen, sulfur, and phosphorus. These soils are naturally poorly drained and have high water-holding capacities. Wetlands are often drained for conversion to other land uses, and the drainage water pumped into adjacent wetlands and aquatic systems.

In many areas of the United States, organic soils that formed as wetlands have been drained for agricultural use. A classic example is the drainage of more than one million acres of histosols in South Florida for agriculture (sugarcane, vegetables, and other crops). A commonly occurring result of drainage of organic soils is a decrease in soil depth, commonly referred to as *subsidence* or oxidation. The

1. This document is SL 302, one of a series of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date July 2009. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
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overall loss is estimated to range from 0.6 to 1 inch per year for the Everglades Agricultural Area (Shih et al., 1998). Subsidence rates are closely related to the water-table depth, and potential adverse effects include increased *hydrophobicity* of soils after drying and the release of nutrients to the environment. Initially after drainage, soil is compacted due to water loss and becomes more hydrophobic, which retards rewetting and encourages greater nutrient runoff. However, over the long-term, microbial oxidation is the primary driving factor for subsidence.

Environmental Effects of Wetlands Drainage

Water-level drawdown or drainage of wetlands can produce major changes in soil physical, chemical, and biological properties. Organic soils in wetlands developed under flooded conditions where organic matter accumulation exceeded its decomposition. Deposition and accumulation of plant material over time resulted in increases of soil depth. Maintenance of these organic soils then depends on the continuation of processes that led to its development.

To understand processes occurring after drainage of organic soils, it is important to understand organic matter decomposition and how it is affected by hydrologic conditions (flooding, drying) and effects of decomposition on nutrient generation from organic matter. As wetlands were drained for water control, agriculture, or other uses, the primary processes leading to the development of their organic soils, such as flooding, were removed. Thus, these areas subsequently underwent subsidence and became sources of C in the atmosphere. Other major concerns of drainage of organic soils include the release of nutrients contained within the organic matter and their potential loss to proximal aquatic ecosystems.

Hydrologic Conditions

Drainage of flooded soils has a significant impact on diffusion of oxygen and other gases in soil, which regulates nutrient stability and mobility. Drainage forces the soil to change from an anoxic (anaerobic) to oxic (aerobic) system. Most chemical processes then increase in rate, including oxygen diffusion into soil and changes in redox chemistry, which enhance rates of nutrient cycling and microbial activity. Drainage exposes more volume of the soil to oxygen and alters the conditions which led to development of wetland soils. Following drainage, oxygen is rapidly consumed and resupplied by the atmosphere, leading to more rapid chemical changes than those occurring under flooded conditions. Results such as increased decomposition of organic matter, greater nutrient mineralization, greater carbon dioxide production and emission, and altered nutrient retention and release are the effects of water withdrawals and the subsequent increase in exposure to oxygen.

Vegetation and Microorganisms

Since microbial activity is greater in aerobic than anaerobic soils, water withdrawals enhance microbial activity, which stimulates organic matter decomposition and nutrient generation. The major effect of drainage in the ecosystem occurs belowground, where organic matter decomposition by heterotrophic microorganisms is significantly greater under drained than flooded conditions (Wright and Reddy, 2001). Thus, wetlands that sequestered C would release C back to the atmosphere upon drainage. Changes from flooded to drained conditions in soils stimulate changes from aquatic to terrestrial vegetation and decrease the algal contribution to total primary production. Drainage of organic soils then has the effect of removing a source of net primary production (algae) and carbon sequestration.

Nutrients

As a consequence of soil oxidation, nutrients contained within organic matter are released. This in turn functions to provide microorganisms with a nutrient supply to continue further oxidation. Water withdrawals from wetlands stimulate organic matter decomposition in areas because drainage creates a larger aerobic zone in soil. These areas in wetlands exhibit enhanced decomposition and release metals and nutrients contained within organic matter, as well as increase dissolved organic matter concentrations. The ultimate fate of these mineralized components will depend on vegetation and environmental conditions. Some nutrients can be taken up by wetland vegetation. However, nutrients in wetland floodwater are mobile and may eventually be exported to rivers or lakes. When this happens, nutrient concentrations increase and microbial activity is stimulated, possibly leading to undesirable consequences such as eutrophication, algal blooms, and fish dieoffs.

Much attention has focused on nutrient runoff from drained organic soils of the Everglades Agricultural Area, particularly with regard to phosphorus. Soil oxidation and mineralization of nutrients followed by runoff were designated as important factors leading to eutrophication of the Everglades wetlands. The problems arise in predicting off-site movement of nutrients released during decomposition, as this movement, especially for phosphorus, is often mediated by reactions with soil minerals. Some soil nutrients such as nitrate and sulfate are more mobile in soils and prone to export during precipitation or drainage events.

Restoration of Wetlands

Agricultural lands adjacent to ecologically sensitive aquatic systems are being acquired by state and federal agencies, and in many cases, converted back to their natural condition. Many of these lands were intensively used for agriculture with a long history of application of fertilizers and pesticides. The first step in the restoration efforts of these lands is the re-establishment of hydrologic conditions through flooding. Initial flooding of these lands poses potential water quality problems as dissolved nutrients stored in these soils can be released into the water column. With time after flooding, wetland vegetation becomes established and is able to absorb many of these nutrients. Thus, the proper management of hydrologic conditions and vegetation are critical for reestablishment of wetlands.

Summary

Many studies have shown that oxidation of organic soils is primarily dependent on water-table depth. Drainage of organic soils stimulates microbial oxidation and subsidence and increases nutrient generation, which may pose environmental hazards to rivers and lakes. Inorganic nutrients generated in wetlands are mobile and their concentration in runoff may increase after water withdrawal. Total greenhouse gas emissions would be higher under drained than flooded soils as a result of higher microbial metabolism, but the end products differ. Drained wetland soils emit carbon dioxide as the endproduct of microbial activity, while flooding increases the production of methane and nitrous oxide. Export of dissolved organic matter and nutrients from wetlands will likely occur after water withdrawal or drainage, but this export is also dependent on wetland vegetation and environmental conditions.

For More Information

Shih, S.F., B. Glaz, and R.E. Barnes. 1998. Subsidence of organic soils in the Everglades Agricultural Area during the past 19 years. Soil Crop Sci. Soc. Fl. Proc. 57:20-29.

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